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Determining Student Activities via Compromised-Analytic Hierarchy Process and 0-1 Integer Programming to Maximize SETARA Points and Satisfy Chickering Theory

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Abstract

Prioritizing and making decisions on what student activities to be selected and conducted to fulfill the aspiration of a university requires some understanding on the mission of the university as translated in its strategic plan and the basic theory on student development. For government funded universities in Malaysia, the recent budget cut imposed by the Malaysian government has made the task more difficult. In this paper, we illustrated how 0-1 integer programming (0-1 IP) model was implemented to select which activities among the forty activities proposed by the student body of Universiti Utara Malaysia (UUM) to be implemented for the 2017/2018 academic year. Two different models were constructed. The 0-1 IP model was developed to determine which activities to be selected based on RM50,000 total budget allocated by the UUM management towards fulfilling the SETARA-rating requirements as well as the Chickering's student development theory. The selection of activities was also based on maximizing the preference of the members of the student body whereby the preference value for each activity was determined using Compromised-Analytic Hierarchy Process. The optimal result obtained using LINGO version 11 revealed that the budget allocated was more than enough to fulfill all the needed requirements. The technique used in this study will be useful and suitable to be implemented by organizations with key performance indicator-oriented programs and having limited budget allocation issues.

Keywords: Chickering theory; Compromised-AHP; UUM-student activity planning; 0-1 integer programming.

1. Introduction

In a university setting, other than students' self-discovery, student development activities are normally planned and conducted under the supervision of the student affairs department. At Universiti Utara Malaysia (UUM) for instance, the student affairs officers, together with the Student Body would sit together to discuss and plan activities that they feel suitable and can attract many participants. Unfortunately, in the past, more often than not, many of these activities were poorly planned and executed. Some of the activities were designed at a very last minute while the others were organized to suit the needs of some particular groups of students only. Consequently, the intended objectives of most activities failed to be realized. In some other cases, the budget allocation for the activities was mostly spent for the earlier activities, leaving none or not enough for the later activities. Proper planning and proper budget allocating are therefore, crucial.

The planning and budgeting becomes even more important for UUM for two reasons:

i. The introduction of a university rating system SETARA by the Malaysian government to rate the performance of local universities using a star rating ranging from 1-Star to 6-Stars (Anonymous, 2017), based on the points accumulated by the university. One of the components that contributes to the total points is the total number of student development activities conducted by the university. Inevitably, UUM has to strategize in order to secure as many points as possible towards achieving a 6-Star rating.

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ii. The need for a comprehensive student development activity to produce well-rounded graduates (Malaysia Education Blueprint 2015-2025, 2014), thus requiring some input from the student development theories to be embedded in the student activity planning.

However, with the recent budget cut by the Malaysian government for public universities (Anonymous, 2017), the task becomes monumental. The pupose of this paper is therefore to share our experience at UUM in planning for the 2017/2018 academic year's student development activities that can i) achieve UUM's target in maximizing the SETARA points achieved from student development activities within the total budget allocated by the UUM management, ii) maximize students' preferences for those activities and iii) fulfil one of the student development theories, i.e. Chickering theory.

In the sections that follow, we described all the processes, step by step, starting with the brainstorming session by the student body to determine all the potential activities to be conducted along with the budget required for each activity, followed by the prioritization of the activities based on students preference score using Compromised-Analytical Hierarchy Process, and lastly, the selection of the final list of activities to be conducted using 0-1 integer programming model.

2. The Activity Selection Process

The UUM student development activities' selection process was conducted through the following two phases of planning activities.

Phase 1: The brainstorming session. Immediately after the end of the 2016/2017 academic year, a group of students comprising of the newly-elected UUM Student Body representatives attended a two-day workshop to prepare proposals for suitable activities to be implemented for the 2017/2018 academic year. During the workshop, the group was introduced to the SETARA-rating instrument, Chickering theory, as well as the UUM Strategic Plan by the student affairs department officers. Under the UUM Strategic Plan, the UUM Student Body was given the responsibility to handle two agendas which are then transformed into a number of student development activity types to be conducted as given in Table 1. The number of activities to be conducted were decided based on the SETARA requirement, if UUM were to achieve the full mark under SETARA's student development activity component.

Next, the group was asked to prepare proposals for the activities that they think are suitable to achieve the target, along with the proposed budget requirement for each activity. A total of 40 activities was put forward. The list of the activities and the amount (in RM) required for each activity are as given in Table 2.

Table-1. List of Activity Types and the Number of Activities to be Conducted for Each Activity Type

Agenda 1: To produce students with multiple competencies	
Student activity type	Total activities to be conducted
A: Festivals, concerts, cultural, and special events	11
B: Programs that promote local culture	1
C: Enculturation of cross-cultural sensitivity programs	3
D: Collaborations with alumni and post-graduates	2
E: Collaboration with CEDI	2
F: Comprehensive global exposure/engagement	2
Agenda 2: To increase graduate employability	
Student activity type	Total activities to be conducted
G: New career advisor programs for students	1
H: Employer engagement sessions	1
I: Organized career fairs	1
J: Programs that focus on students' generic skills.	6

Table-2. Proposed Activities and Total Amount Requested in RM

Activity	**RM**	**Activity**	**RM**	**Activity**	**RM**
1	1500	-	-	38	500
2	1500	-	-	39	2500
3	500	-	-	40	3000

Phase 2: The ranking of activities using Compromised-Analytic Hierarchy Process. 100 students comprising of 25 students from each academic year were asked to participate in this exercise. None of these students were involved in the Phase 1 activity. The purpose of this exercise was to gauge the students' opinion with regards to the activities proposed in Phase 1 as well as to ensure that the activities to be selected match the students' interests and preferences. Students' preferences were captured in the form of preference weights, which were calculated using a technique called Compromised-Analytic Hierarchy Process (C-AHP) (Nazri *et al.*, 2016) as illustrated here: Firstly,

each student was asked to rate his level of preference towards each activity using a value ranging from 1 (representing least preferred) to 9 (representing most preferred). This technique was utilized to ensure that the inconsistency issue that appears in the standard AHP technique can be avoided.

To illustrate, suppose that student A gave these following ratings:

Table-3. Preference Rating by Student A

	Rating								
Activity	1	2	3	4	5	6	7	8	9
1					√				
2				√					
-					.				
39									√
40									√

The evaluation was then transferred into a Saaty's pairwise comparison matrix $C = [c_{ij}]_{40x40}$ [4] as follows: Suppose that the evaluator rated activity i as w_i and activity j as w_j. Then c_{ij} which is the pairwise comparison value between activity i and activity j was determined using formula (1).

$$\text{Let } b = w_i - w_j. \text{ If } b > 0 \text{ then } c_{ij} = b+1; \quad \text{If } b = 0 \text{ then } c_{ij} = 1; \quad \text{If } b < 0 \text{ then } c_{ij} = 1/(1-b) \qquad (1)$$

Having applied (1), the pairwise comparison matrix for student A based on the evaluation as illustrated in Table 3 is as given by matrix C_A. The C_A matrix represents the pairwise AHP-matrix introduced by in (Saaty R. W., 1987) and c_{ij}-value represents the preference level of activity i over activity j, as indicated by the scales in Table 4. Next, using *Expert Choice*, an AHP software, each student's comparison table was checked for consistency and later, translated into preference ranking or weight of each activity under each stage/year using the standard Saaty's AHP method (Saaty T. L., 2008). The group preference ranking was calculated by taking the geometric average score of all the students' pairwise comparison matrix instead of the simple arithmetic mean to preserve group consistency as suggested by in Lootsma (1993). The results are presented in Table 5. These weight values were used as part of the parameters needed in the 0-1 integer programming model (IP). For a complete steps of Saaty's standard AHP, please refer to in Kousalya *et al.* (2012).

$$C_A = \begin{bmatrix} 1 & 2 & . & . & . & 1/5 & 1/5 \\ 1/2 & 1 & . & . & . & 1/6 & 1/6 \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ 5 & 6 & . & . & . & 1 & 1 \\ 5 & 6 & . & . & . & 1 & 1 \end{bmatrix}_{40x40}$$

Table-4. Preference scale for Saaty's AHP pair-wise comparisons

Preference Level	Numeric Value
Equally preferred	1
Equally to moderately preferred	2
Moderately preferred	3
Moderately to strongly preferred	4
Strongly preferred	5
Strongly to very strongly preferred	6
Very strongly preferred	7
Very strongly to extremely preferred	8
Extremely preferred	9

Note: When activity i compared to j is assigned one of the above numbers, the activity j compared to i is assigned its reciprocal

Table-5. The Activity Weights Given by C-AHP

Activity	1	2	3	…	8	9	10
Weight	.025	.009	.045	…	.014	.025	.009
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
Activity	31	32	33	…	38	39	40
Weight	.025	.014	.025	…	.025	.014	.045

Prior to this modeling, upon closer inspection, the student affairs department officers realized that some of the proposed activities could actually serve more than one student activity type. Consequently, the officers then mapped the proposed activities against the student activity types. The results are as given in Table 6.

Table-6. The Mapping of Proposed Activities, Against Student Activity Types

Activity	Agenda 1									Agenda 2
	A	B	C	D	E	F	G	H	I	J
1	-	-	-	-	-	√	-	√	-	√
2	√	-	-	-	-	-	-	-	-	√
3	-	-	-	-	-	√	-	-	-	√
4	-	√	-	-	-	-	-	-	-	√
5	-	√	√	-	-	√	-	-	-	√
-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-
36	√	-	-	-	√	√	-	√	-	√
37	√	-	-	-	√	√	-	√	-	√
38	√	-	-	√	√	√	-	-	-	-
39	√	-	-	√	-	-	√	√	√	√
40	√	-	-	√	√	√	√	√	√	√

At the same time, to suit the Chickering's student development theory, each activity was also mapped according to its intended participants (i.e. whether the activity is tailored for first, second, third or fourth year students) as shown in Table 7.

Chickering theory was created by Arthur (Chickering and Reisser, 1993) to explain the process of identifying development, specifically to examine the identity development process of students in higher education. The theory examines the identity development process by means of seven vectors of development which contribute to the development of identity. We then grouped the vectors according to the academic year of the students at UUM:

i. Year 1 - Developing competence and managing emotion.
ii. Year 2 - Moving through autonomy toward interdependence and developing mature interpersonal relationships.
iii. Year 3 - Establishing identity and developing purpose.
iv. Year 4 - Developing integrity.

Table-7. The Mapping of Proposed Activities, Against Student Academic Year

Activity	Academic Year			
	1	2	3	4
1	-	-	√	√
2	√	√	√	√
3	√	√	√	√
4	√	√	√	√
5	-	-	-	√
-	-	-	-	-
-	-	-	-	-
36	√	√	√	√
37	√	√	√	√
38	√	√	√	√
39	√	√	√	√
40	√	√	√	√

3. The 0-1 Integer Programming Models' Formulation and the Results

The applications of 0-1 IP are common among practitioners when dealing with resource allocation and selection processes. Examples include, among others, applications in fire resource management (Donovan and Rideout, 2003), healthcare resource allocation (Earnshaw and Dennett, 2003), research and development budget funding (Eckhause *et al.*, 2012), advertising budgets (Ichikawa *et al.*, 2009), airlift capacity planning (Stannard *et al.*, 2006), IT investments (Kearns, 2004), operating room time (Blake and Donald, 2002), and drug development budget allocation (Patel *et al.*, 2013). In our case, we developed the 0-1 IP model to maximize the total student preference value based on budget, SETARA-rating, and Chickering theory constraints. The 0-1 IP model is as follows:

Decision variable: $X_i = 1$ if activity i is selected; 0 otherwise, where $i = 1,2,3,\ldots\ldots,40$.

Objective function: To maximize total student preference = $0.025X_1 + 0.009X_2 + 0.045X_3 + 0.025X_4 + 0.014X_5 + 0.009X_6 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots + 0.014X_{34} + 0.014X_{35} + 0.025X_{36} + 0.025X_{37} + 0.025X_{38} + 0.014X_{39} + 0.045X_{40}$

Subject to

i. Budget constraint whereby the total amount allocated by the UUM management is RM50,000.00.

$1500X_1 + 1500X_2 + 500X_3 + 1000X_4 + 550X_5 + 750X_6 + 700X_7 + 1500X_8 + 1000X_9 + 650X_{10} + 8000X_{11} + 750X_{12} + 500X_{13} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots + 1000X_{34} + 1500X_{35} + 1500X_{36} + 750X_{37} + 500X_{38} + 2500X_{39} + 3000X_{40} \leq 50000$

ii. The minimum number of activities required for each activity type as listed in Table 1:

A. $X_2 + X_8 + X_{10} + X_{13} + X_{15} + X_{17} + X_{18} + X_{24} + X_{25} + X_{26} + X_{27} + X_{28} + X_{29} + X_{30} + X_{31} + X_{36} + X_{37} + X_{38} + X_{39} + X_{40} \geq 11$

B. $X_4 + X_5 + X_8 + X_{10} + X_{13} + X_{15} + X_{17} + X_{18} + X_{24} + X_{27} + X_{28} + X_{29} + X_{30} + X_{31} + X_{35} \geq 1$

C. $X_5 + X_8 + X_9 + X_{11} + X_{13} + X_{15} + X_{18} + X_{27} + X_{28} + X_{30} + X_{32} \geq 3$

D. $X_{12} + X_{14} + X_{19} + X_{21} + X_{22} + X_{23} + X_{33} + X_{38} + X_{39} + X_{40} \geq 2$

E. $X_8 + X_9 + X_{12} + X_{14} + X_{24} + X_{33} + X_{34} + X_{35} + X_{36} + X_{37} + X_{38} + X_{40} \geq 2$

F. $X_1 + X_3 + X_5 + X_6 + X_7 + X_8 + X_{11} + X_{12} + X_{14} + X_{19} + X_{20} + X_{27} + X_{30} + X_{32} + X_{34} + X_{36} + X_{37} + X_{38} + X_{40} \geq 2$

G. $X_{12} + X_{14} + X_{19} + X_{21} + X_{22} + X_{33} + X_{39} + X_{40} \geq 1$

H. $X_1 + X_7 + X_{12} + X_{13} + X_{14} + X_{19} + X_{21} + X_{22} + X_{23} + X_{33} + X_{34} + X_{36} + X_{37} + X_{39} + X_{40} \geq 1$

I. $X_{12} + X_{14} + X_{19} + X_{21} + X_{22} + X_{23} + X_{33} + X_{39} + X_{40} \geq 1$

J. $X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8 + X_9 + X_{10} + X_{11} + X_{12} + X_{13} + X_{14} + X_{15} + X_{16} + X_{17} + X_{18} + X_{19} + X_{20} + X_{24} + X_{25} + X_{26} + X_{27} + X_{28} + X_{29} + X_{30} + X_{31} + X_{32} + X_{33} + X_{34} + X_{35} + X_{36} + X_{37} + X_{39} + X_{40} \geq 6$

iii. The Chickering theory constraint – the student affairs officers wanted to make sure the total number activities to be conducted for all the students' academic levels to be equal.

The 0-1 IP model was run using LINGO version 11 and the result obtained is as given in Table 8.

Table-8. Result for 0-1 IP Model

Activity Selected	Cost	Fulfilling the Requirement for Activity Type									
		A	B	C	D	E	F	G	H	I	J
X2	1500	√	-	-	-	-	-	-	-	-	√
X3	500	-	-	-	-	-	√	-	-	-	√
X4	1000	-	√	-	-	-	-	-	-	-	√
X7	700	-	√	√	-	-	√	-	-	-	√
X8	1500	-	-	-	-	-	√	-	-	-	√
X9	1000	-	-	-	-	-	√	-	√	-	√
X13	500	√	√	√	-	-	-	-	-	-	√
X15	1000	√	√	√	-	-	-	-	-	-	√
X17	500	√	-	-	-	-	-	-	-	-	√
X18	1500	√	√	√	-	-	-	-	-	-	√
X21	700	-	-	-	√	-	-	√	√	√	-
X23	1500	-	-	-	√	-	-	-	√	√	-
X24	3000	√	√	-	-	√	-	-	-	-	√
X25	700	√	-	-	-	-	-	-	-	-	√
X26	700	√	-	-	-	-	-	-	-	-	√
X27	1500	√	√	√	-	-	√	-	-	-	√
X28	750	√	√	√	-	-	-	-	-	-	√

Table-8. (Cont'd)Result for 0-1 IP Model

Activity Selected	Cost	Fulfilling the Requirement for Activity Type									
		A	B	C	D	E	F	G	H	I	J
X29	750	√	√	-	-	-	-	-	-	-	√
X30	700	√	√	√	-	-	√	-	-	-	√
X31	2000	√	√	-	-	-	-	-	-	-	√
X32	700	-	-	√	-	-	√	-	-	-	√
X34	1000	-	-	-	√	√	-	√	√	√	√
X35	1500	-	-	-	-	√	√	-	√	-	√
X36	1500	-	√	-	-	√	-	-	-	-	√
X37	750	√	-	-	-	√	√	-	√	-	√
X38	500	√	-	-	-	√	√	-	√	-	√
X39	2500	√	-	-	√	√	√	-	-	-	-
Total Budget Required = RM30,450.00; Total Preference Value = 0.745											

4. Discussion

Based on the optimal result as shown in Table 8, a total of 27 out of 40 proposed activities was recommended to be implemented in the 2017/2018 academic year.

Table-9. Analysis for SETARA requirement

Total Activities	**Activity Type**									
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Minimum Required	11	1	3	2	2	2	1	1	1	6
Total Suggested	16	12	8	4	7	11	2	7	3	24

The total budget required is RM30,450.00 out of RM50,000.00 allocated and the total preference value is 0.745 out of the maximum value of 1.000. Also, the total suggested activities that can fulfil the minimum requirement for each activity type exceeds the minimum requirement as shown in detail in Table 9, by quite a significant margin except for three activities, i.e. activities type D, G, and I.

5. Conclusion

In this paper, we illustrated the use of 0-1 IP model and C-AHP in selecting the suitable UUM undergraduate student activities to fulfil the SETARA-rating requirement and Chickering's student development theory while at the same time, maximizing students' preference and ensuring that the total budget required does not exceed the total budget allocated by the UUM-management. Utilizing this 0-1 IP model gives two significant advantages to the UUM-management in general, and specifically to the student affairs officers:

i. Although the UUM-management allocated RM50,000.00 to the Student Body, the 0-1 IP model output suggested that in order to fulfil all the requirements, only RM30,450.00 would be needed. Therefore, the remaining RM9,550.00 can be used to either i) organize a few other selected activities form the list of the activities that have not been selected by the 0-1 IP model, taking into consideration, the students' preference, or ii) increase the budget allocated for the selected activities since the current practice of the UUM-management is to provide only 70 percent of the actual amount needed to run each activity (the other 30 percent must be secured by the Student Body themselves through activity fees or sponsorships).

ii. Since the number of activities suggested exceeds the minimum required number of activities to achieve the full SETARA points, if some of the activities failed to be actually implemented, the probability that the full SETARA points cannot be realized will be minimized.

The next stage of this study will involve the scheduling of all the selected activities to increase the total student participation as well as to ensure that there will be no time conflict among the activities, i.e. to minimize the chances of activity failure.

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